National Aeronautics and Space Administration

Quantifying OH Abundance with Spatial Heterodyne Spectroscopy

Principal Investigator: Vijay Natraj (329); Co-Investigators: Seyedeh Sona Hosseini (322), Robert Spurr (RT Solutions, Inc.)

Program: FY21 R&TD Innovative Spontaneous Concepts

Objectives

The objective was to perform radiative transfer modeling studies to evaluate the abundance of the hydroxyl radical at different altitudes and for different viewing geometries from airborne (including rocket-based) spatial heterodyne spectroscopic measurements.

Background

The hydroxyl (OH) radical has a significant influence on the photochemistry of the atmosphere. Solar resonance fluorescence around 308 nm has been traditionally used to quantify OH abundance. However, to date, instruments measuring OH, such as those used in the MAHRSI experiment, have been very bulky and have significant power requirements. Recently, an ultracompact Spatial Heterodyne Spectrometer (SHS) developed by our team was selected for tech demo on the Blue Origin rocket by the NASA Flight Opportunities program. However, due to the lack of algorithms to model OH solar resonance fluorescence, this opportunity cannot at present be used to obtain scientific atmospheric measurements.

Approach and Results

We employ the quasi-spherical VLIDORT-QS radiative transfer (RT) code developed (by PI Natraj and Co-I Spurr) as part of a project funded by the NASA Atmospheric Composition Campaign Data Analysis and Modeling program to retrieve ice cloud optical properties from high-altitude aircraft measurements. This code was recently updated to handle high-resolution OH stimulated emission in the ultraviolet. Previous treatment of this emission has focused on limb-view transmission modeling with corrections for Rayleigh scattering and ozone absorption; the new VLIDORT-QS model encompasses a full scattering treatment of the polarized radiation field, along with a linearization capability for generating analytically-calculated Jacobians (weighting functions) with respect to the temperature and OH volume mixing ratio (VMR) profiles. The OH capability is based on upper-atmosphere OH VMR profiles of OH, with stimulated emission expressed in terms of temperature-dependent "g-factors" (emission rate factors) characterizing OH solar fluorescence.

We work with a granule of data from Microwave Limb Sounder (MLS) observations. The OH VMR profiles are screened for quality and selected for five different solar zenith angles. RT calculations are performed using a native spectral resolution of 0.0085 nm (832 points from ~304–311 nm), with Gaussian convolution using a half width at half maximum of 0.02 nm. The camera height was varied from 30 to 80 km in 5 km increments. The solar zenith and azimuth angles are fixed at 50 and 10 degrees, respectively, with view zenith angles ranging from 180 (nadir) to 60 degrees. The OH VMR data is used to define a 42-layer pressure grid from 0.0001 to 1000 hPa. The temperatures and heights are interpolated from the US Standard atmosphere to this grid, as are O3 and NO2 VMRs. A Rayleigh scattering atmosphere is assumed. The OH "spike levels" are then compared against the smooth background field (Rayleigh + O3 absorption). Results are shown in Figures 1–3. The overall aim is to carry out a linear-analysis sensitivity study to characterize error budgets for SHS measurements.

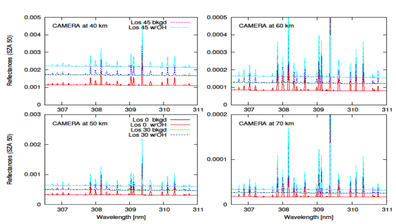

Figure 1: Simulated reflectances for SHS measurements

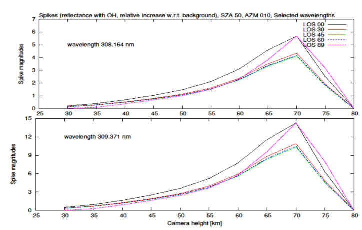

Figure 2: Spike magnitudes for two wavelengths

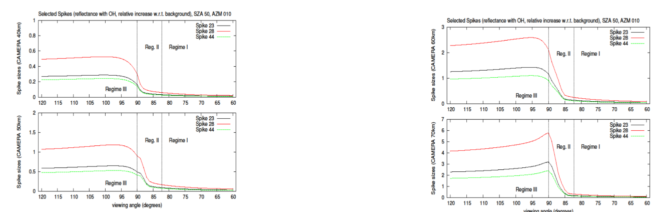

Figure 3: Spike magnitudes as a function of viewing angle for camera at (left) 40 and 50 km, and (right) 60 and 70 km

Significance/Benefits to JPL and NASA

The project has several benefits for NASA/JPL. The OH radical is a key oxidative species in the upper atmosphere, and monitoring OH provides information on chemistry, as for example described in models, as well as information on the atmospheric reaction to climate change. The methods developed in this project thus position JPL to continue OH monitoring with state-of-the-art experimental methods. The SHS spectrometer is a novel technique which would significantly simplify spaceborne observations of OH, as well as many other trace gases and atmospheric parameters. While our project focused on OH, the lessons learned here will benefit any potential future applications of the SHS technique for environmental monitoring (e.g., for solar induced fluorescence). Much of the project was dedicated to expanding the VLIDORT-QS RT model to OH emissions. Previous versions of this code, which are freely available, have been used at JPL, NASA, and many other research institutions. The expanded capabilities of VLIDORT-QS thus benefit JPL, NASA, and the community. Overall, given the increasing interest in obtaining key niche science measurements from low-cost mission concepts, this effort is very timely for showcasing the critical science objectives and measurements that can be achieved using our novel instrument concept. Simultaneously, this project supports the maturation of a miniature, low-mass, low-volume, high-sensitivity science payload that is suitable for taking full advantage of ever increasing robotic platforms for Earth science applications and beyond.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

PI/Task Mgr Contact
Email: Vijay.Natraj@jpl.nasa.gov

Clearance Number:
RPC/JPL Task Number: R21263